The Early Work of Guglielmo Marconi

Part 1 by F. C. Judd G2BCX

This article is concerned with early experiments carried out by Guglielmo Marconi and in particular the types of antenna he used. At that time (circa 1895) the function of antennas was not fully understood so work in this direction was mostly on an empirical basis, although antennas were destined to play the most important role in the first long distance transmission of wireless waves some six years later.

The essential theoretical data concerned with radiating waves stemmed from the work of James Clerk-Maxwell (circa 1864); the actual existence of these waves remained unproved until 1888 when Professor Heinrich Hertz announced his discoveries, although again no practical applications were developed. At this time Marconi was about 12 years of age. It must be appreciated, however, that virtually all the earlier investigators, Michael Faraday, Joseph Henry, Dolbear, Sir W. H. Preece, Clerk-Maxwell and Hertz were no amateurs but respected and very eminent scientists, many of them Professors, who contributed considerable theory regarding the radiation of electric waves through space. Others, such as Augusto Righi, E. Branly, Alexander Popoff and Nikola Tesla, all carried out experiments in this field and contributed much of the knowledge that was needed to finalise the possibility of wireless transmission over distances other than across the confines of a laboratory.

Guglielmo Marconi was born on 25 April 1874 in the Italian town of Bologna. His father, Giuseppe Marconi, was a wealthy landowner who had married an Irish girl, Annie Jameson, related to the well-known distillers of Irish Whiskey of that name. By nature retiring and studious, the young Marconi often displayed a determination which no doubt ensured the success he achieved in all his work, even that embarked upon at a very early age. Aside from his native Italian, Marconi was acquainted with numerous other languages and spoke both English and French without trace of accent. This was a valuable asset to a man who during the course of his life spent a good deal of his time in England involved with his various "wireless" companies and working in countries all over the world installing and testing wireless equipment as well as carrying out innumerable experiments. He became well known to members of Royal Families of a number of different countries, including our own, and to leading figures everywhere involved with the scientific and practical applications of electricity, magnetism and wireless. As a result of these accomplishments, he was awarded many honours including the G.C.V.O., was President of a number of scientific institutes and was conferred with the degrees of Doctor of Science, Doctor of Law and Doctor of Engineering by a number of notable universities. He was awarded the Nobel prize for physics in 1909 (2).

When Marconi visited Bologna in 1926, thirty years after his first patent in "Wireless" had been granted, he said: *I had the idea, I might also say intuition, that these (wireless) waves might, in a not too distant future, furnish mankind with a new and powerful means of communication usable not only across continents and seas but also on board ships, bringing with it a diminution of the dangers of navigation and abolition of the isolation of those crossing the sea.*(3)

The First Experiments

Although Marconi was greatly influenced by the discoveries of Hertz in 1886 and the experiments carried out by the Italian scientist Augusto Righi with Hertzian waves, he could not understand why the potential applications of such a discovery had not been investigated. For a year he scanned the technical papers of the time for indications of this. Since nothing had appeared he set to work to improve the effectiveness of his own experimental apparatus which at that period was just capable of transmitting a signal from one side of a table to the other (Fig. 1.1).

Still living in Italy his more serious experiments with wireless began in 1895 at his father's country house, the Villa Griffone at Pontecchio, where with poles and wires in the garden and improved wireless apparatus he succeeded in transmitting and receiving signals, first over very short distances but finally achieving a range of 3km. In a matter of six years he progressed from this to sending wireless signals across the Atlantic Ocean between Poldhu in Cornwall and the appropriately named Signal Hill at St. John's in Newfoundland, a distance of 2900km!

Marconi Comes to England

It is perhaps difficult for those acquainted with modern radio communication to realise the problems that Marconi and his assistants had to overcome in the course of his experiments and development of more efficient apparatus. The function of antennas as we know it today was barely understood, there were no valves for amplifying weak signals, or with which to generate radio frequency power. No factory-made components were available so these all had to be made by hand. In his book *Marconi and Wireless,* R. N. Vyvyan, one of Marconi's senior engineers at the time of the transatlantic tests (circa 1901-1905) said: *We knew nothing then about the effect of the length of the wave transmitted governing the distance over which communication could be effective. We did not have the means or instruments for measuring wavelength, in fact we did not know what wavelength we were using.* (1)

Following the experiments in Italy at the Villa Griffone, Marconi travelled to England and on 2 June 1896 applied for provisional protection for his invention. Shortly after he succeeded in getting an introduction to Sir William Preece, Chief Engineer of the British Post Office Telegraphs, who aided Marconi in the development of his systems for spark transmission. First attempts to increase distance resulted in only 6km and it was realised that aside from greater transmitting power and receivers with greater sensitivity that the antennas too had to be much more efficient. An illustration of a transmitting and receiving system used at the time is shown in Fig. 1.2 and it was from the "capacity areas" as they were called that the long wire antenna emerged as an efficient radiator. Marconi found that increasing the length of the lead wire to or from a capacity area increased the working range and eventually these "areas", or mesh plates, were discarded entirely and replaced with a long vertical wire carried by a mast. In order to use longer antennas for much more distant communication the wires were elevated by a kite or balloon. The long wire radiator became the basis for antennas used with all future systems. Marconi may well have related the antenna length and its elevation to the wavelength in use even though this relationship was not then fully understood. But in due course it was.

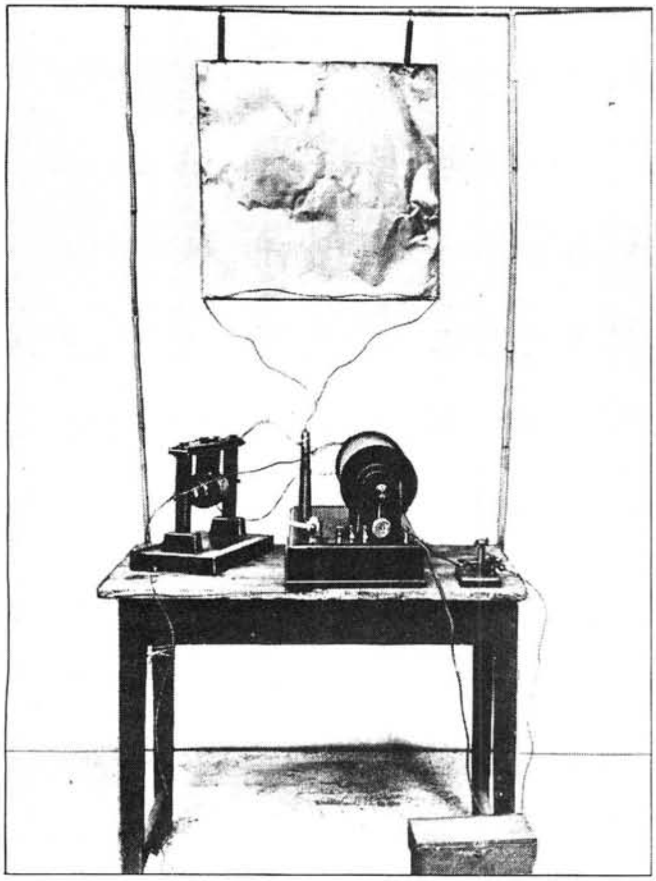

Fig. 1.1: Transmitter used by Guglielmo Marconi during early experiments in Italy during 1895

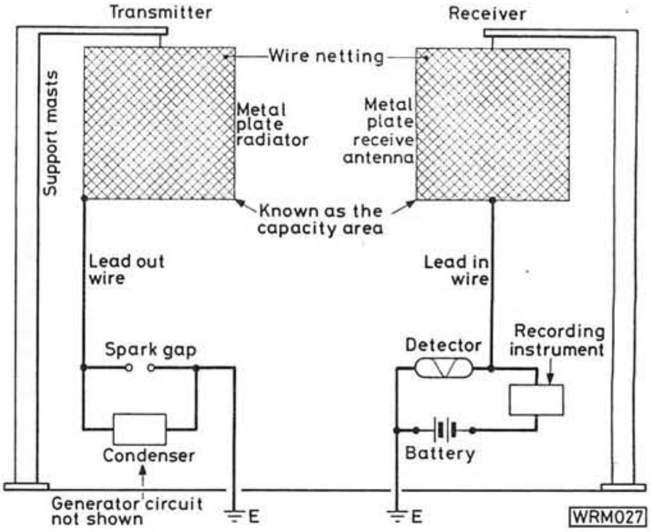

Fig. 1.2: "Capacity Area" antennas used by Marconi probably around 1896 but which gave little improvement in transmitting range (see text)

Meantime many more tests were carried out and demonstrations given to the British Post Office (Fig. 1.3) and other interested organisations as proof that communication by wireless was a viable proposition. By 1897 trials had been carried out over water and between ships and shore-based stations, mostly in Italy and later in England. Indeed antennas appeared in all kinds of places and readers of *Practical Wireless* may be interested to know that a station was set up by Marconi at the Haven Hotel in Poole, not far from the *PW* Offices and with an antenna mast 30m high. Details of this and the story connected with it were published in the March 1981 issue of *PW*. The antenna itself was made from stranded 7/20 copper wire insulated with india-rubber and tape.

Wireless Across the English Channel

About this time the Wireless Telegraph and Signal Company was formed (later to become the Marconi Wireless Telegraph Company). However, in March 1899 an attempt was made to bridge the English Channel and on the 27th of that month signals passed between South Foreland on the East Kent coast and Wimereux near Boulogne, a distance of about 48km. The antenna used was 45m high. There is an amusing sequel to the cross-channel tests. The station at Wimereux was visited by Lord Baden Powell to witness a demonstration of receiving wireless signals from England but at the appointed time and despite continuous calling, no signals were forthcoming. After checking everything and in sheer desperation even installing another receiver, there were still

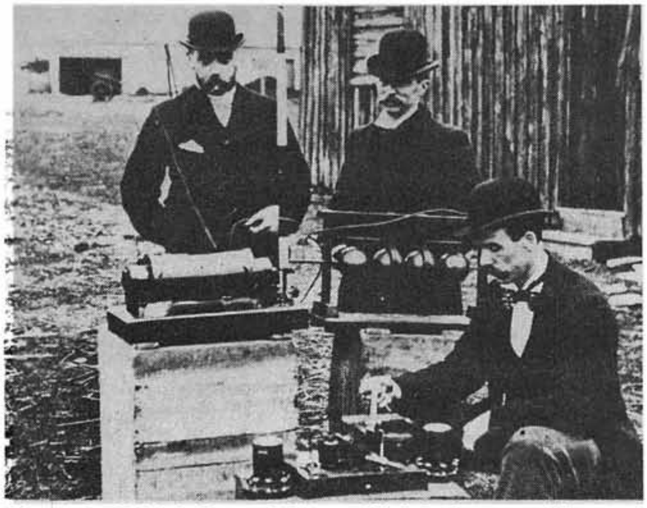

Fig. 1.3: British Post Office officials inspect Marconi wireless apparatus during the Bristol Channel demonstration (May 1897). A distance of 14km over water from Lavernock to Weston-super-Mare was achieved

no signals. Baden Powell realised that it was probably just a breakdown in the equipment but to Marconi himself it was a shattered faith. Suddenly however, in a shed behind the station where they waited, a bell rang and Marconi jumped like a scalded cat. *South Foreland,* yelled a mechanic and South Foreland it was with the following message: *Just back from supper, anything happened your end?* (2)

Tuning

From the experience gained during the first years of design, experiment and practical application, Marconi realised that some means of selective reception (and transmission) was necessary, what we today call tuning which we achieve with a high degree of selectivity because of the wide range of frequencies in use and the narrow bandwidths required. Up to the year 1900 the simple arrangement of the spark gap connected directly to the transmitter antennas in Fig. 1.4(a) offered no means of separation between two stations operating at the same time, i.e. the system was completely non-selective. Even in 1897 Sir Oliver Lodge had pointed out the desirability of being able to tune both transmitter and receiver to the same wavelength in order to secure privacy, or at least separation from other users of wireless communication.

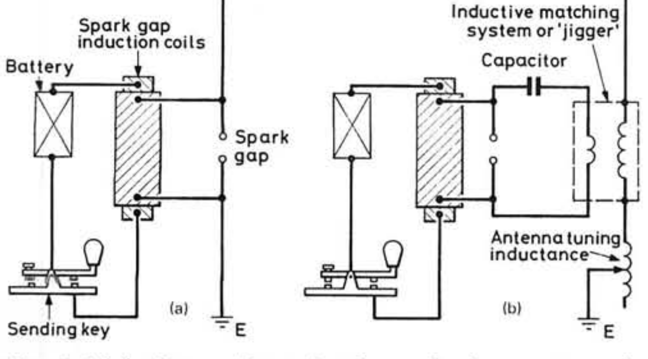
WRM029
Long wire antenna
Spark gap induction coils
Battery
Spark gap
Sending key
(a)
E
Inductive matching system or 'jigger'
Capacitor
Antenna tuning inductance
(b)
E

Fig. 1.4 (a): Transmitter circuit used prior to syntonic tuning. (b) The transmitter circuit with the 7777 patent syntony tuning system

Sir Oliver Lodge had in fact carried out experiments in 1889 to show that resonance, or "syntony" as it was called, could be obtained but his system severely limited the distance over which electro-magnetic waves could be radiated. Marconi's experiments with what we would call h.f. transformers began before 1897, the year in which Lodge had registered a patent for syntony. After many experiments Marconi finally took out patents on circuits that had given the best results and his patent of 1 June 1898 makes clear the desirability of tuning. *It is desirable that the induction coil should be in tune or syntony with the electrical oscillations transmitted. The most appropriate number of turns and most appropriate thickness of wire vary with the length of the wave transmitted.* Since the same applies to receiving, syntony was incorporated in all receivers and after a further series of experiments and developments and the registering of more patents, Marconi took out a master patent, number 7777, on 26 April 1900. Both the patent and the number became famous later in litigation as the famous "four sevens patent" although its validity was finally upheld in High Court — but that is another story and one to be found in the various books about the life and work of this very talented man.

The importance of resonance was that it resulted in a much higher degree of efficiency in each case and allowed the antenna systems to be "tuned" as well. The arrangement of the circuitry of Marconi's syntonic, or tuned, wireless apparatus, under the patent 7777, is shown in Fig. 1.4(b). Incidentally the tuned transformer arrangement coupling the spark generator to the antenna was known as a "Jigger". The antenna tuning section, Fig. 1.4(b), no doubt looks familiar as it is more in keeping with antenna tuning arrangements used at the present time. Tuning was perhaps one of the most important developments in wireless, equal perhaps only to the invention of the valve which was yet to come.

Preparation for the Transatlantic Tests

With the problem of multi-station operation and consequent interference to each other now solved by the use of syntonic tuning, the time arrived for Marconi to attempt greater working ranges. His next venture was in fact to span the Atlantic Ocean. The first step was to find a suitable site for a station on the British mainland as physically near to America as possible and in due course some land overlooking Poldhu Cove in South West Cornwall was obtained. Work on setting up a station began in October 1900. In order that the signals transmitted from Poldhu could be monitored, another station was installed at the Lizard about 10km away. This was to serve not only for checking Poldhu transmissions but as an experimental station for testing syntonic circuits and also to operate as an additional ship-to-shore station. By 23 January 1901 the Lizard station was operational and set a new record, using syntonic tuning, by receiving signals from the Niton, Isle of Wight transmitter at a distance of 300km.

Meantime work at Poldhu had proceeded to a stage where preliminary tests could be carried out. The antenna system consisted of about 400 wires suspended in an inverted cone arrangement from a 61m circle of masts, there being 20 of these each 61m high. The wavelength was estimated at 366 metres (820kHz). The antenna is illustrated in Fig. 1.5. The next stage was to install a station in the USA. Marconi and one of his senior engineers, R. N. Vyvyan, travelled across to the selected site at Cape Cod in Massachusetts where Vyvyan remained to supervise the construction. Meantime, however, and in June of that year, transmissions from Poldhu were not only being

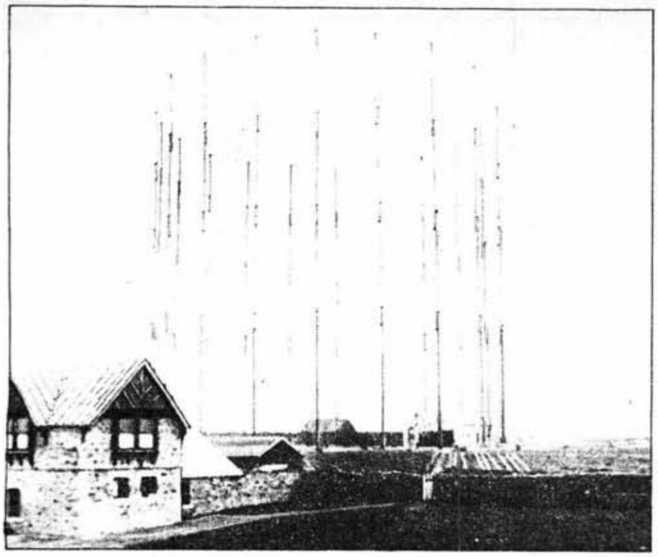

Fig. 1.5: Original antenna array at Poldhu prior to the transatlantic tests. This antenna was blown down by gale force winds before the tests could be carried out

received well at Niton but also from another new station at Crookhaven, County Cork in Ireland, at a distance of 365km. This had proved that radiated signals were not leaving the earth's surface at a tangent but were in fact following the curvature of the earth in some way. Little was known then of radio wave propagation but this made things look more promising for successful transatlantic tests. However, disaster struck later at Poldhu when gale force winds brought down the whole antenna system and its 20 masts. Worse was to follow, because on November 26 the complete ring of masts already set up by R. N. Vyvyan for the Cape Cod antenna, a replica of the one at Poldhu, suffered the same fate. Some £50 000 had already been spent on this scheme with nothing to show for it but a hopeless tangle of antenna wires and fallen masts and a now very depressing situation. With his usual determination and the help of a senior assistant, G. S. Kemp, Marconi set up a temporary antenna at Poldhu and made plans to use an alternative location on the other side of the Atlantic, namely St. John's, Newfoundland. What transpired is reserved for Part 2 but is described by W. J. Baker in his book *A History of the Marconi Company* rather appropriately as "The Atlantic Gamble".

References

1. *Marconi and Wireless*. R. N. Vyvyan. E.P. Publishing Ltd. (1974)
2. *Marconi Master of Space* (biography). B. L. Jacat and D. M. B. Collier. Hutchinson & Co.
3. *Pioneers of Wireless*. Ellison Hawks FRAS (1927). Methuen & Co. Ltd.

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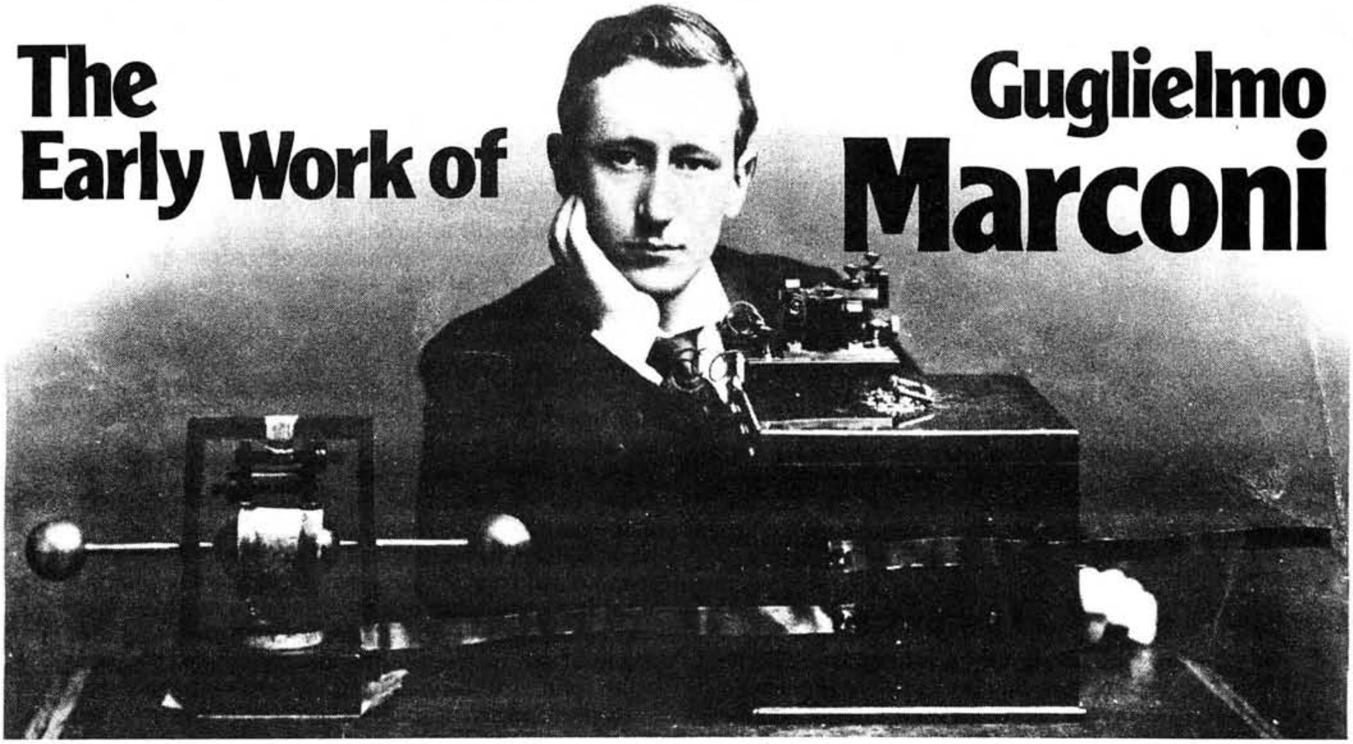
The Early Work of Guglielmo Marconi



Part 2 by F. C. Judd G2BCX

Before Marconi's achievement in sending wireless signals across the Atlantic Ocean he was trying to squash rumours of doubt about the accuracy of wireless communication ranges he had so far covered. His objective was of course to put "wireless" in competition with the long distance undersea cable telegraph systems operating at the time. The existing British Post Office monopoly and similar restrictions imposed in other countries had made it virtually impossible to provide a paying inland wireless telegraph service. His proposal to attempt sending wireless signals across the Atlantic was however considered somewhat foolhardy because, apart from the cost already incurred in this venture, an objection had been raised about the power needed to cover a distance of nearly 3200km and which might seriously interfere with existing ships' wireless communications. But Marconi had already proved that with his "syntonic" tuning there was little possibility of this.

The Transatlantic Tests

Marconi was almost ready for his Atlantic tests when the antennas at both Poldhu in Cornwall and at Cape Cod in the USA, to be used for the tests, were virtually destroyed by gale force winds. The Marconi Company board of directors also became very concerned. A large amount of money had been spent on this venture and now there was nothing to show for it. This was September 1901, the disaster with the antennas having occurred on the 17th. By the 24th a temporary antenna as illustrated in Fig. 2.1 had been set up at Poldhu and was ready for operation by the 26th. Although plans were available for the construction of a new permanent antenna at Poldhu, Marconi decided not to wait and not to use the Cape Cod station. The antenna there had been wrecked anyway. Instead he decided to use the Poldhu station with the temporary antenna for transmitting and the next best site he could find across the Atlantic at St. John's, Newfoundland for reception.

On November 27 he set sail with G. S. Kemp and another assistant named Paget, with receiving equipment, kites, balloons and antenna wire etc., and reached St. John's on December 6. A survey of the area showed the most likely location for the receiving station as Signal Hill (a name in keeping with the project) and which was about 180m above the St. John's harbour. By December 9 all the receiving equipment was set up, earthing systems were laid and a balloon was made ready to hoist a long wire antenna. The final task was to send a cable to Poldhu arranging for the letter "S" in Morse code (three dots) to be transmitted continuously from 3pm to 7pm GMT, the transmissions to start on December 11. Incidentally there was a reason why the letter "S" was chosen as the test signal. Firstly it could be sent automatically and would be easier to distinguish should heavy static prevail, which was in fact the case. Also, keyed signals of longer duration, e.g. dashes, would have put a greater load on the transmitter which was being run to its absolute limit.

The transmissions from Poldhu began as scheduled, the transmitter being run at a power of between 10 and 12 kilowatts on a wavelength of approximately 366 metres (820kHz), or at least so it was thought. At Signal Hill they were using a balloon supported antenna but George Kemp was having trouble with this because of very strong winds. The receiver in use employed the "syntonic" tuning operating with a self-restoring coherer detector, a device which functioned almost as a semi-conductor.

However, nothing was heard that could be identified as the letter "S" and Marconi thought the reason might be due to movement of the antenna in the high wind, this, in turn, causing detuning at the receiver. By the 12th the gale was still in full force so a kite was sent up with twin 155m antennas but this was soon carried away completely. Another kite was launched, this time with a single 152m wire and Marconi continued to listen patiently as the allotted time for the transmission of that day was coming to an end. Then, shortly after midday Newfoundland time, Marconi asked Kemp to listen in order to confirm that he too could hear the three dots that were now being received. Kemp confirmed that they were indeed readable despite the crashing noise of static. In a notebook Marconi simply wrote—Sigs. at 12.30, 1.10 and 2.20. His aim had been achieved and history had been made.

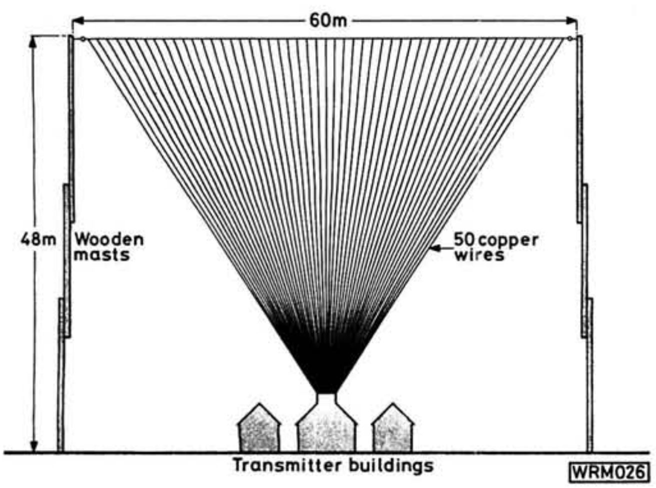


Fig. 2.1: The temporary antenna system set up by Marconi and G.S. Kemp at Poldhu and which was used for transmitting the first wireless signals across the Atlantic Ocean to St. John's, Newfoundland

The weather became worse, however, but in spite of the gale still blowing three more kite antennas were released but they would not stay up, although for a brief period the signals were heard again. On the 14th (Saturday) the weather had still not let up and kite flying became impossible so in sheer desperation George Kemp with help from local people rigged a long wire antenna from Signal Hill to an iceberg that had floated into St. John's harbour—but to no avail. Tests just could not be continued under such appalling weather conditions. It was to be a case of waiting until the weather abated so that a kite or balloon supported antenna could be maintained in a stable condition.

The fact that both Marconi and Kemp had heard and identified the signals was not in itself real proof, except to themselves, that they had been heard at all. They had been too weak to activate the Morse ink recorder which would have provided more concrete proof. Marconi was therefore doubtful whether to make the news public. He did, however, inform the London office on December 14 of success and on the 16th allowed the news to be released to the press.

Problems but More Success

Then another problem arose. The Anglo-American Telegraph Company informed Marconi that they had a monopoly on communication throughout Newfoundland and threatened him with legal action if he continued his tests. Although this was work of a scientific nature and Marconi was not transmitting messages, he decided to find another location. Canada or the USA were equally suitable and there were no restrictions in these countries either.

Then his feat in receiving wireless signals transmitted across the Atlantic was queried. Did it really happen? This was to some extent understandable as there was only Marconi's and Kemp's own confirmation that the signals had been received from Poldhu. Doubt was also expressed as to whether his wireless waves could have followed the curvature of the earth(3).

Marconi realised that more concrete evidence was needed to satisfy those who did not believe that long distance transmission was possible. On February 22 he sailed for Canada in a ship called the Philadelphia, an American Line vessel whose owners had permitted him to install a large antenna on the ship. At this time the Poldhu station had been improved and could send messages of some length. Marconi's idea was of course another attempt to provide absolute proof that the transmission of wireless signals across the Atlantic was possible and accordingly he arranged for a Morse ink recorder to be connected to the ship's receiving equipment. Complete messages were received and recorded when the Philadelphia was 2500km from Poldhu and the letter "S" signals were heard at a distance of 3400km. His proof was now ink recorded messages signed by the ship's master, Captain Miles. Also during this voyage Marconi discovered what he called the "night effect", in that after dark it was found that transmission ranges became much greater.

The Transatlantic Service

Marconi's next journey was to Ottawa to select a site suitable for a station for Transatlantic service, the final choice being a place called Table Head at Glace Bay, Nova Scotia. Meantime more experiments, developments and tests had taken place and Marconi's real task now was to establish reliable long range wireless communication for commercial use. The Glace Bay station was his one hope of providing proof that such a service was possible.

The antenna at Glace Bay, as shown in Fig. 2.2, consisted of 400 wires suspended from triatics stretched between four 61m towers constructed of wood with the wires brought together at the lead-in position to the transmitter building. This inverted square cone somewhat resembles an upturned discone antenna but it could be used either as a whole or in sections.

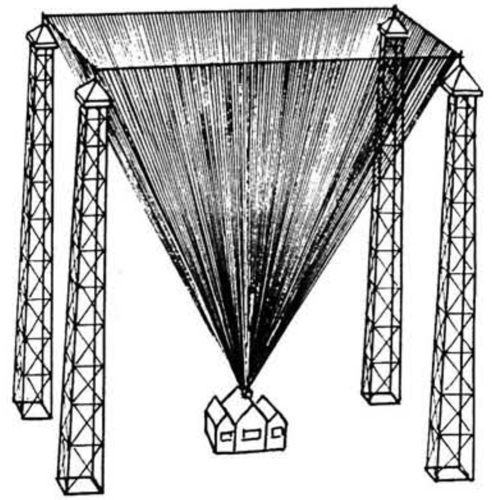


Fig. 2.2: The original Glace Bay (Nova Scotia) antenna for transatlantic service erected 1902

The first transmissions were made on 19 November 1902 but nothing was heard at Poldhu. On the 25th weak signals were received and then only after a number of modifications had been made to circuits and the antenna. However, by December 5 the first really readable signals from East to West across the Atlantic were received and recorded as well but enthusiasm was damped somewhat when on the following night and under the same conditions as far as equipment was concerned, nothing was heard at all. At the time there was no explanation for this and the reason only became known some time later when the existence and behaviour of the ionospheric layers had been discovered.

Marconi was of course unable to explain these seemingly peculiar results to the press and again his own prestige and that of the Marconi Company was at stake. Although propagation conditions were variable they did not always prevent transmissions being made and received in either direction. On December 14 and for a period of 2 hours very good signals were received. Marconi therefore decided to take a chance on declaring that the Transatlantic service would be opened with a special message to be sent the following night, on December 15. He was fortunate in two ways. Conditions remained good and the Times correspondent, a Dr. Parkin, was to be present when his own message to the newspaper in London was the one to be sent. It was received "solid" as we might say today. Conditions on the following night also proved to be suitable for transmission and messages were sent to the then King, Edward VII and to a General Brusati in Rome.

So the transatlantic service began, limited at first and its validity still doubted by some, but progress was made during the coming years despite many setbacks and technical problems. During that period Dr. J. A. Fleming had produced the diode valve which he demonstrated to Marconi on the 16 November 1904. Fleming was a consultant to the Marconi Company and continued to be until he died on 18 April 1945 at the age of 95.

Directional Antennas

One final notable development must be recalled and this concerns what Marconi called "directional antennas". The term directional can of course apply to an antenna that radiates equally in all directions around it and is said to be "omni-directional". By 1905 an entirely new antenna had been erected at Glace Bay with a view to increasing the communication range still further. This particular antenna is shown in Fig. 2.3 and was probably omni-directional. It consisted of an "umbrella" of wires, 200 in all, supported by the original four masts at the centre (as in Fig. 2.2) from which wires ran out laterally to two concentric rings of masts each 55m high, with eight in the inner circle (not shown in the illustration) and 16 for the outer circle. Provision was made to increase the diameter of the "umbrella" sections, if needed, by using another outer circle of 48 masts each 15m high. The diameter of the antenna without the extension was 677m but with the extension would be 885m. The results with this enormous antenna were more than satisfying with reception during daylight hours up to 2880km. But Marconi, never completely satisfied, carried on with tests and improvements until in June 1905 two-way communication was established during the daytime between Glace Bay and Poldhu, this time using a much longer wavelength.

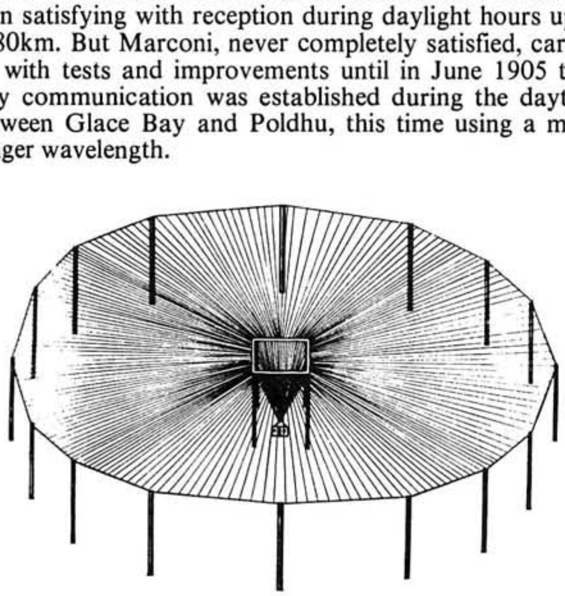


Fig. 2.3: A completely modified antenna at Glace Bay erected 1905 (see text for details)

Marconi made an interesting discovery whilst carrying out experiments at Poldhu. He found that a long wire laid along the ground gave much stronger reception when its free end was pointing in a direction away from the transmitter. Much the same applied to inverted "L" antennas and he eventually registered a patent on what was known as the "bent antenna", as shown in Fig. 2.4, for directional transmission and reception. As a result instructions were sent to Glace Bay to take away three-quarters of the "umbrella" section leaving only one section facing away from England. Reception of the Glace Bay signals at Poldhu increased quite considerably. Was this the first unidirectional antenna?

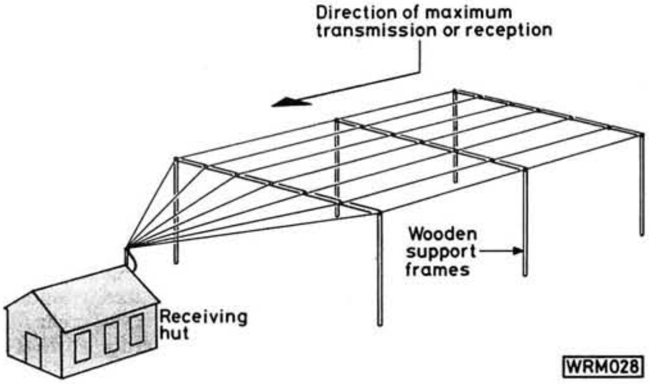


Fig. 2.4: Marconi's patent "bent antenna" for directional transmission and reception

In Conclusion

G. Marconi has been described as an enigma of a man who shunned social contact with anyone he did not really know and yet he was always pleased with news that wireless had been the means of saving life. He had constantly maintained that one of his primary objectives with wireless was to ensure safety at sea but thinking perhaps of the uses it was put to during World War I and the destructive part it may have been responsible for, he was known to have said "Have I done the world good, or have I added a menace".

The Marchese Marconi GCVO died following a heart attack on 20 July 1937. If the registration of his first patent in wireless in 1896 marks the beginning of the era of wireless then its centenary is yet to be celebrated.

The author would like to thank the present Marconi Company of Chelmsford for information, photographs and illustrations used in this article and for permission to quote from the book *A History of the Marconi Company* by W.J. Baker.$^{(3)}$ This and the book given as Ref. 1 are recommended and deal more with the technical aspects of developments that stemmed from the work of Marconi. The book$^{(2)}$ is an informative and impartial biography of Marconi whilst the remaining book$^{(4)}$ *Pioneers of Wireless* contains much detail about famous scientists and their discoveries in magnetism, electricity and wireless including the work of Marconi. Whilst some of the books may be out of print they should be available from the larger public libraries and are well worth reading.

References

1. *Marconi and Wireless.* R.N. Vyvyan. E.P. Publishing Ltd. (1974)

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4. *Pioneers of Wireless.* Ellison Hawks FRAS (1927). Methuen & Co. Ltd.